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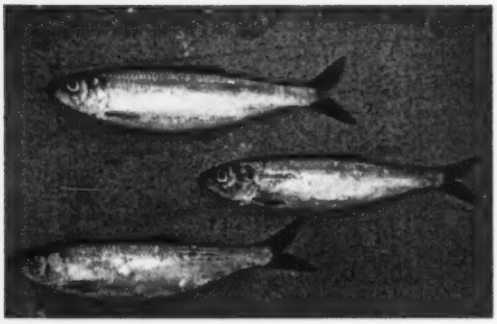
Pacific Region
Canadian Science Advisory Secretariat
Science Advisory Report 2011/061

STOCK ASSESSMENT REPORT ON PACIFIC HERRING IN BRITISH COLUMBIA IN 2011



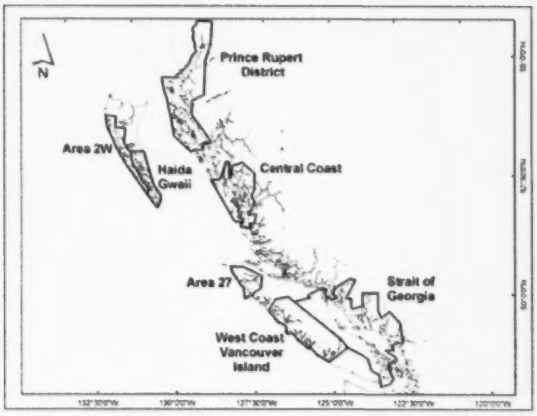


Figure 1. The five major and two minor British Columbia herring stock assessment regions

Context

Pacific herring is a pelagic species inhabiting inshore and offshore waters of the North Pacific. In the eastern Pacific, herring distribution ranges from California to the Beaufort Sea. Herring annually migrate between feeding and spawning areas. Fish mature and recruit to the spawning stock primarily between ages 2 and 5. In British Columbia (BC) herring predominantly recruit at age 3. BC herring stocks are managed based on five major and two minor stock areas. The five major BC herring stocks are Haida Gwaii(Area 2E), Prince Rupert District, Central Coast, Strait of Georgia, and West Coast of Vancouver Island, while the two minor herring stocks are Area 2W and Area 27 (Figure 1). Catch and survey information is collected independently for each of these seven areas and science advice is provided on the same scale.

Fisheries Management Branch annually requests science advice regarding the status of herring stocks in BC and harvest options. Annual stock assessments and forecasts of abundance are carried out using a catch-at-age model. This report summarizes the results of the 2011 annual assessment and provides recommendations on 2011/12 harvest options.

This Science Advisory Report has resulted from a Fisheries and Oceans Canada, Canadian Science Advisory Secretariat Pacific Regional Advisory Meeting. Additional publications from this process will be posted as they become available on the DFO Science Advisory Schedule at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

SUMMARY

- The five major BC herring stocks are Haida Gwaii (Area 2E), Prince Rupert District, Central Coast, Strait of Georgia, and West Coast of Vancouver Island, while the two minor herring stocks are Area 2W and Area 27 (Figure 1).

Canada

- The Fishery Management Framework establishes harvest control rules setting the maximum available commercial harvest for each of the major stock areas at 20% of the forecast of mature stock biomass (males and females combined) when the forecast of mature stock biomass is above the commercial fishery threshold or "cutoff." The cutoff is established as 25% of estimated unfished biomass (0.25 B_0). If a forecast exceeds a cutoff, but a 20% harvest rate would result in spawning biomass that is less than the cutoff, the maximum available harvest is determined as the difference between the forecast and cutoff.
- A new integrated statistical catch age model (ISCAM) was used to assess the 2011 herring spawning stock biomass and forecast of the 2012 pre-fishery mature stock biomass. Key differences between ISCAM and the HCAM model used previously relate to the scaling of the spawn abundance index, parameterization of fishing gear selectivity, and the likelihood assumption for the age composition data. The time series of abundance trends from ISCAM and HCAM are comparable, but ISCAM resulted in biomass estimates that are larger.
- Given that a number of alternative assumptions were implemented in developing the new ISCAM model, and insufficient evaluation of the effects of these changes on existing harvest control rules occurred, it is recommended that a more comprehensive evaluation of the ISCAM model and its impact on the decision rules for the herring assessment be conducted.
- The following is a summary of the assessment results and advice by management area. Abundances are reported in metric tons (tonnes).

Haida Gwaii (Area 2E)

- All herring spawning from Cumshewa Inlet in the north to Louscoone Inlet in the south are assumed to be part of the Haida Gwaii stock.
- No commercial herring fishery occurred in this area in 2011 (or 2003-2010).
- The median estimate of the 2011 spawning stock biomass (and 95% confidence interval) is 16,579 (7,700-33,630) tonnes.
- The forecast of mature stock biomass for 2012 is 9,618 tonnes (assuming poor recruitment), which is below the fishing threshold of 0.25B_0 (10,436 tonnes).
- Stock abundance has remained at relatively low levels and there is uncertainty about the cause of its current low productivity. Given that there has been limited stock recovery, even in the absence of commercial fisheries, an assessment to determine appropriate rebuilding and harvest strategies is recommended prior to reopening fisheries in this area.

Prince Rupert District

- All herring spawning in Statistical Areas 3 to 5 are assumed to belong to the Prince Rupert District stock.
- In 2011, the total roe herring seine fishery validated catch was 883 tonnes (approximately 14% of the total coast-wide catch) and the total roe herring gillnet fishery validated catch was 1,264 tonnes (approximately 19% of the total coast-wide catch).
- The median estimate of the 2011 post fishery spawning biomass (and 95% confidence interval) is 27,046 (14,340-50,590) tonnes.
- The forecast of mature stock biomass for 2012 is 27,492 tonnes (assuming average recruitment), which is above the fishing threshold of 0.25B_0 (19,641 tonnes).
- Retrospective analysis of abundance estimates for this stock suggests that the forecast biomass has been biased high in recent years. The tendency to overforecast stock abundance is not evident in the other areas and warrants caution in fishery management decisions around harvest levels due to the increased level of uncertainty.

Central Coast

- All herring spawning in Kitasu Bay (a portion of Statistical Area 6), in Statistical Area 7, and in part of Statistical Area 8 (Kwakshua Channel and Fitzhugh Sound) are assumed to be part of the Central Coast stock.
- No commercial herring fishery occurred in this area in 2011 (or 2008-2010).
- The median estimate of the 2011 spawning biomass (and 95% confidence interval) is 14,666 (7,280-27,280) tonnes.
- The forecast of mature stock biomass for 2012 is 11,357 tonnes (assuming poor recruitment), which is below the fishing threshold of $0.25B_0$ (15,600 tonnes).
- Stock abundance has remained at relatively low levels and there is uncertainty regarding the reason for the current low productivity. Given that there has been limited stock recovery, even in the absence of commercial fisheries, an assessment to determine appropriate rebuilding and harvest strategies is recommended prior to reopening fisheries in this area.

Strait of Georgia

- All herring spawning in Statistical Areas 14 to 19, 28 and 29 (excluding Section 293), and part of 13 (Herring Sections 132 and 135, Deepwater Bay area south) are assumed to belong to the Strait of Georgia herring stock.
- In 2011, the roe herring seine fishery total allowable catch was 6,999 tonnes; however the fishery was not opened due to a large recruitment of small fish and roe size. The total roe herring gillnet fishery validated catch was 4,415 tonnes (approximately 67% of the total coast-wide catch).
- The median estimate of the 2011 spawning biomass (and 95% confidence interval) is 125,261 (70,430-217,950) tonnes.
- The forecast of mature stock biomass for 2012 is 138,448 tonnes (assuming good recruitment), which is above the fishing threshold of $0.25B_0$ (35,013 tonnes).

West Coast Vancouver Island

- All herring spawning in Statistical Areas 23 to 25 are assumed to belong to the West Coast of Vancouver Island herring stock.
- No commercial fishery occurred on the west coast of Vancouver Island in 2011 (or 2006-2010).
- The median estimate of the 2011 spawning biomass (and 95% confidence interval) is 14,679 (6,990-27,630) tonnes.
- The forecast of mature stock biomass for 2012 is 15,321 tonnes (assuming poor recruitment), which is above the fishing threshold of $0.25B_0$ (14,894 tonnes).
- Stock abundance has remained at relatively low levels and there is uncertainty about the cause of its current low productivity. Given that there has been limited stock recovery, even in the absence of commercial fisheries, an assessment to determine appropriate rebuilding and harvest strategies is recommended prior to reopening fisheries in this area.

Area 2W

- All herring spawning in Statistical Area 2W (except Herring Section 006) are assumed to belong to this Haida Gwaii minor stock.
- No commercial spawn-on-kelp fishery occurred in this area in 2011.
- The median estimate of the 2011 spawning biomass (and 95% confidence interval) is 5,448 (1,920-13,610) tonnes.
- The forecast of mature stock biomass for 2012 is 5,398 tonnes (assuming average recruitment).

Area 27

- All herring spawning in Statistical Area 27 are assumed to belong to this West Coast of Vancouver Island minor stock.
- A small commercial spawn-on-kelp fishery occurred in this area in 2011.
- The median estimate of the 2011 post fishing spawning biomass (and 95% confidence interval) is 1,077 (500-2,370) tonnes)
- The forecast of mature stock biomass for 2012 is 1,124 tonnes (assuming average recruitment).

INTRODUCTION

Species Biology

Pacific herring is a pelagic species migrating between inshore spawning and offshore feeding areas of the North Pacific. In the eastern Pacific, herring distribution ranges from California to the Beaufort Sea. Herring mature and recruit to the spawning stock predominantly at age 3 within British Columbia but age-at-recruitment tends to increase with latitude within this range.

Stock Structure

For the purposes of evaluation and management, British Columbia herring stocks are defined as five major and two minor stocks (Figure 1). Stock structure is supported both by multi-year tagging and genetic studies (Hourston, 1982, Beacham et al., 2008, Flostrand et al., 2009). The major stocks are: Haida Gwaii (HG, Area 2E and formerly referred to as Queen Charlotte Islands), Prince Rupert District (PRD), Central Coast (CC), Strait of Georgia (SOG) and West Coast of Vancouver Island (WCVI). The two minor herring stocks are Area 2W and Area 27. Smaller scale spatial delineations related to fishing and sampling activities are Statistical Areas (http://www.pac.dfo-mpo.gc.ca/fm-gp/maps-cartes/areas-secteurs/index-eng.htm) and Herring Sections (http://www.pac.dfo-mpo.gc.ca/science/species-especes/pelagic-pelagique/herring-hareng/herspawn/pages/default0-eng.htm).

Ecosystem Considerations

As a forage species, herring play a key role in the marine ecosystem and are a food source for a variety of species (Schweigert et al., 2010). However, there is little information available to develop ecosystem-based conservation limits for herring. The harvest rate of 20% of the mature biomass should ensure that a large fraction of the spawning-stock biomass is available to predator species or is protected for future production (Hall et al. 1988).

Herring are an important prey species to many piscivores including Pacific hake, halibut, arrowtooth flounder, and dogfish. They are also believed to be important in the diet of marine mammal predators such as Steller and California sea lions, harbour and northern fur seals, harbour porpoises, Pacific white-sided dolphins, and humpback whales. Because no targeted commercial harvest of immature herring takes place, most juveniles remain available to support ecosystem processes. Research continues to develop a fuller understanding of ecosystem processes and the role that herring play in maintaining ecosystem integrity and function.

History of the Fishery

Herring have been harvested for many years to provide a variety of food products. First Nations have traditionally harvested herring and herring spawn for food, social and ceremonial purposes, and continue to do so today. From the early 1930s to the late 1960s, herring were commercially harvested and processed (reduced) into relatively low-value products such as fishmeal and oil. Figure 2 shows trends depicting total quantities of commercial removals from 1951 to 2011. Commercial catches increased dramatically in the early 1960s but were unsustainable. By 1965, most of the older fish had been removed from the spawning population by a combination of overfishing and by a sequence of weak year-classes attributed to unfavourable environmental conditions and a low spawning biomass. As a result, the commercial fishery collapsed and was closed by the federal government in 1967 to permit the resource to rebuild. During the closure from 1967-1971, limited fishing activity occurred at low levels (Hourston, 1980). At this time, there was a growing interest in harvesting roe herring for export to Japan, where herring stocks had become decimated. A small experimental roe harvest began in 1971 and expanded rapidly until 1983, when fixed quotas were introduced to regulate the catch. A series of above average year-classes occurred in the early 1970s, rapidly rebuilding stocks and permitting the re-opening of areas for commercial fishing. Today, the fishery is comprised of: commercial fishing opportunities for food and bait herring, spawn-on-kelp products, and roe herring; a food, social, and ceremonial fishery for First Nations; and recreational opportunities. Table 1 shows combined commercial removals from 2007 to 2011 from roe and food and bait (includes special use) fisheries operating in the five major BC herring stock assessment areas.

Table 1. Combined commercial removals from roe,and food and bait (includes special use) fisheries operating in the five major BC herring stock assessment areas (tonnes), 2007-2011. Removals associated with the spawn-on-kelp fishery are not included in totals.

	2007	2008	2009	2010	2011
Haida Gwaii	0	0	0	0	0
Prince Rupert District	970	1,662	2,000	1,484	2,147
Central Coast	398	0	0	0	0
Strait of Georgia	9,822	9,934	10,170	8,324	5,128
West Coast Vancouver Island	0	0	0	0	0

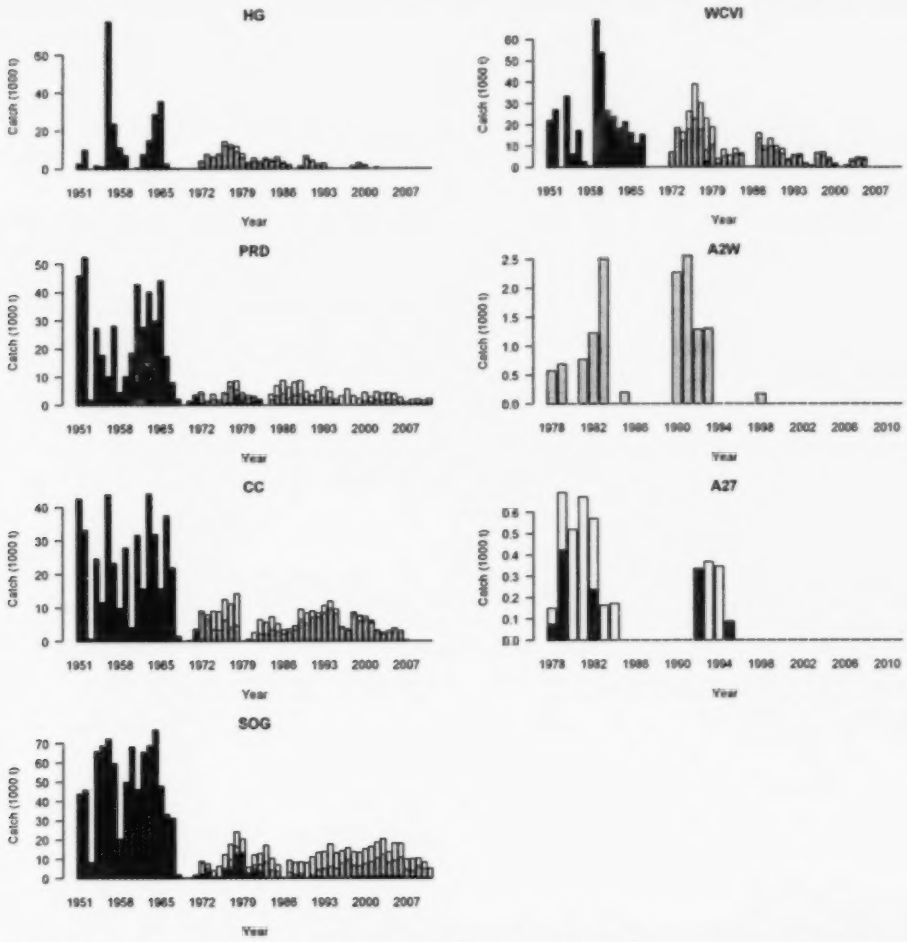


Figure 2. Historical catch of herring in the five major (1951-2011) and two minor (1978-2011) stocks for the winter purse seine fishery (dark bars): seine-roe fishery (grey Bars), and gill net fishery (light grey bars). Spawn on kelp fishing not represented. Catch units are in thousands of metric tons and scales differ between figures.

Management Framework

The objective of the current herring management framework is to sustainably manage the available biomass in a manner that conserves and protects Pacific herring stocks, their habitat, and ecosystem processes, and provides fishing opportunities for First Nations, commercial, and recreational harvesters. The present-day fishery is managed using a management framework developed based on previously reviewed and endorsed science advice (Haist et al. 1986, Stocker, 1993) that incorporates a fixed harvest rate policy and a formal harvest control rule, in the form of a commercial fishing threshold or "cutoff."

Maximum available commercial harvest for each of the major stock areas is 20% of the forecast of mature stock biomass (males and females combined) when the forecast of mature stock biomass is above the commercial fishery threshold or "cutoff." If a forecast exceeds a cutoff but a 20% harvest rate would result in spawning biomass that is less than the cutoff, the maximum available harvest is determined as the difference between the forecast and cutoff. The cutoff for each major area is established as 25% of the estimate of unfished biomass (B_0). Prior to this

year's assessment, the estimates of unfished biomass and corresponding cutoffs were based on 1996 estimates of B_0, while this year's assessment revises the estimates of B_0. Past simulation studies support the use of cutoffs in their ability to maintain the reproductive capacity of each major stock (Haist et al. 1986, Stocker, 1993).

Maximum available commercial harvest for the minor herring stocks (Area 2W and Area 27) is calculated by applying a precautionary 10% harvest rate to the forecast of mature stock biomass. Commercial fishery thresholds are not established for minor stock areas and recruitment is assumed to be average.

An evaluation of compliance of the current management framework with the DFO Policy, *A fishery decision-making framework incorporating the precautionary approach* (DFO, 2009) has been conducted and supports the current approach (Cleary et al 2010).

Rationale for Assessment

Advice was requested by Fisheries Management on the status of the five major and two minor herring stocks and forecasts of biomass for 2012 by stock area for application of the BC herring management framework.

ASSESSMENT

Methodology and Sources of Information

Data collected for use in the assessment of herring stocks are: spawn survey data, commercial catch landings, and age composition data taken from biological samples of the commercial fishery, test fishery charters, and research catches. Herring stock assessment uses information from biological samples for determining the population age composition and average weight-at-age, historical catch, and an assessment of the distribution and intensity of egg deposition in each stock assessment area.

The annual herring stock assessment produces estimates of current abundance, spawning biomass and recruitment, as well as forecasts of mature stock biomass (pre-fishery) for the upcoming year. Responding to recommendations in 2010 for a review of the previous herring catch-at-age model (HCAM) a new integrated statistical catch age model (ISCAM) was developed and endorsed for use in determining stock status and provision of harvest advice. Significant differences between HCAM and ISCAM are related to the estimation of the spawn survey catchability coefficients; the parameterization of gear selectivity; the likelihood assumption for the age-composition data; pooling of age-composition data for rare age-classes (<2%), and a distribution assumption for the steepness parameter for modeling recruitment. Modeling changes affected the scaling of spawn survey results and the time series estimates of abundance.

Stock Trends and Status

Time-series estimates of total biomass at the start of the year and the spawning stock biomass are presented in Figure 3. Table 2 presents estimates of the 2011 spawning biomass, estimates of unfished biomass, and depletion ratios for the major stock areas.

Haida Gwaii (QCI 2E)

Spawning biomass for the stock is estimated at 16,579 tonnes in 2011, an increase from 11,248 tonnes in 2010. During the past decade, recruitment has tended to be poor. The 2011 age-3 recruitment was determined to be average. The recruiting age-3 fish comprised 44% of the 2011 returns, whereas the age-4 and age-5 fish contributed 8% and 31%, respectively. There has been little evidence of stock recovery in this area, despite the absence of commercial fishing over most of the past decade.

Prince Rupert District

Spawning biomass for the stock is estimated at 27,046 tonnes in 2011, an increase from 24,130 tonnes in 2010. During the past decade, age-3 recruitment has been average or good, with the exception of 2004 and 2009 which were poor. The 2011 age-3 recruitment was determined to be average. In 2011, recruiting age-3 fish contributed 24%, age-4 fish contributed 24% and age-5 fish contributed 17% of the adult stock.

Central Coast

Spawning biomass for the stock is estimated at 14,666 tonnes in 2011, increasing from 10,726 tonnes in 2010. Over the past decade, age-3 recruitment has fluctuated between average and good with two poor years, 2008 and 2010. The 2011 age-3 recruitment was determined to be good. The recruiting age-3 fish dominated the 2011 returns accounting for 49%, whereas the age-4 and age-5 fish contributed only 15% and 24%, respectively. There has been little evidence of stock recovery in this area, despite the absence of commercial fishing since 2008.

Strait of Georgia

Spawning biomass for the stock is estimated at 125,261 tonnes in 2011, increasing from the 2010 level of 66,556 tonnes. Age-3 recruitment during the past decade has been average or better in all years, except for poor recruitment in 2008 and 2010. Some of the largest recruitment levels observed in the past 60 years occurred in the early 2000s, and the 2004 and 2006 year-classes. The 2008 year-class recruiting in 2011 was determined to be good. The recruiting age-3 fish comprised 65% of the 2011 mature stock biomass, whereas age-4 and age-5 fish contributed 6% and 19%, respectively.

West Coast Vancouver Island

Spawning biomass for the stock is estimated at 14,679 tonnes in 2011, increasing from 6,887 tonnes in 2010. Abundance in 2007 through 2011 is below the lowest level observed in the 60-year time series of data for this stock. Age-3 recruitment during the past decade has been poor or average, except for good in 2002 and 2003. The 2011 age-3 recruitment was determined to be average. The recruiting age-3 fish comprised 63% of the 2011 returns, whereas the age-4 and age-5 fish contributed 23% and 8%, respectively. There has been little evidence of stock recovery in this area, despite the absence of commercial fishing since 2006.

Area 2W

Spawning biomass for the stock is estimated at 5,448 tonnes for 2011, an increase from the 2010 level of 4,047. The recruiting age-3 fish comprised 50% of the 2011 returns, whereas the age-4 and age-5 fish contributed 18% and 23%, respectively.

Area 27

Spawning biomass for the stock is estimated at, 1077 tonnes in 2011, a decrease from the 2010 estimate of 1,257 tonnes. The majority of the 2011 run consisted of age-3 fish, contributing 39% of total returns. Age-4 and age-5 fish contributed 24% and 27%, respectively.

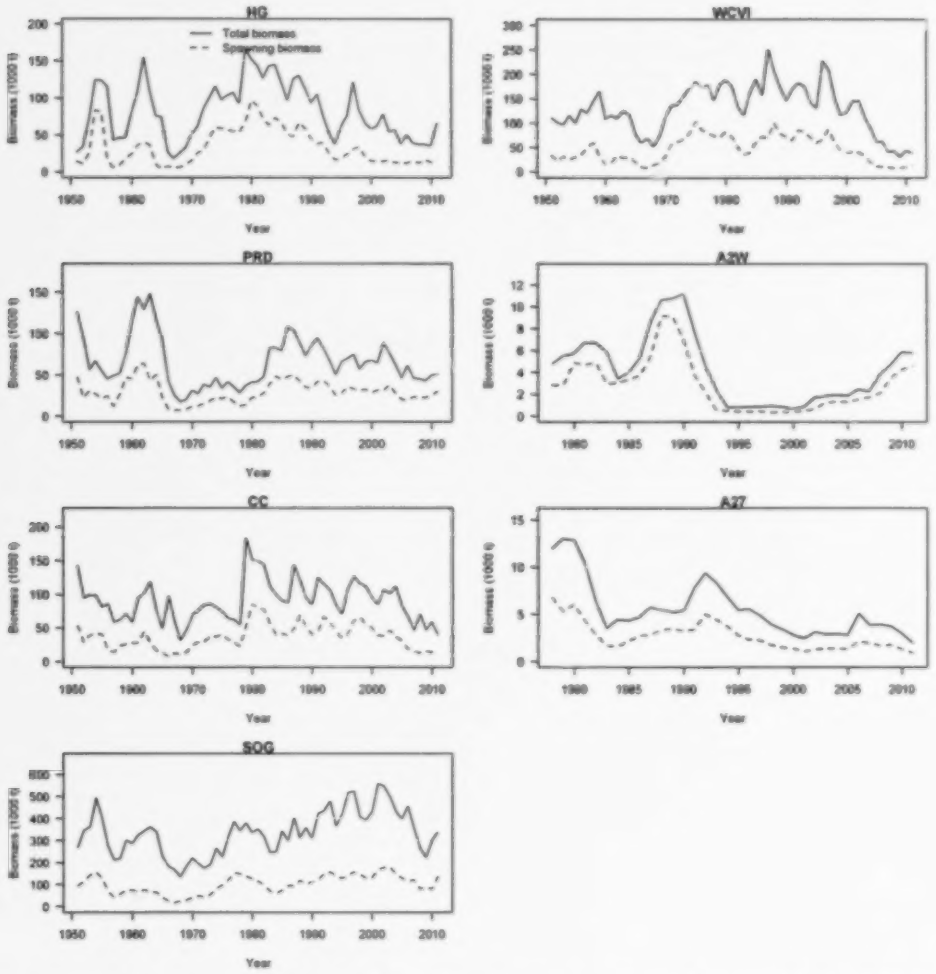


Figure 3. Estimates of total biomass at the start of the year (numbers times empirical weight-at-age) and spawning stock biomass (post fishery). Note: y-axis scales differ in each figure. And the x-axis differ between the major and minor areas.

Table 2 Median (and 95% confidence interval) estimates of the 2011 spawning biomass (SB_{2011}), unfished biomass(B_0), and depletion ratios (SB_{2011}/B_0) for the major stock areas. Amounts are given in tonnes.

	SB_{2011}			B_0			SB_{2011}/B_0		
Stock	**Median**	**2.50%**	**97.50%**	**Median**	**2.50%**	**97.50%**	**Median**	**2.50%**	**97.50%**
HG	16,579	7,700	33,630	41,740	30,050	61,510	0.39	0.19	0.75
PRD	27,046	14,340	50,590	78,560	54,150	150,180	0.34	0.15	0.68
CC	14,666	7,280	27,280	62,400	48,470	85,060	0.23	0.12	0.41
SOG	125,261	70,430	217,950	140,050	110,470	184,240	0.89	0.53	1.45
WCVI	14,679	6,990	27,630	59,580	46,840	78,530	0.24	0.12	0.43
Area 2W	5,448	1,920	13,610	3,240	1,750	7,190	1.68	0.59	3.65
Area 27	1,077	500	2,410	2,410	1,520	4,000	0.44	0.22	0.91

Biomass Forecasts for 2012

For the major areas, forecasts of mature stock biomass are made by adding estimates of surviving repeat spawners to estimates of age-3 recruits. Recruitment of age-3 fish is estimated as the number of age-3 fish recruited to the stock at the end of each year prior to the fishery. Recruitment is categorized as poor, average or good, and model estimates of recruitment are calculated as the means of the lower 33%, middle 33% and upper 33% of the number of age-3 fish over the entire time series.

Recruitment scenario is determined for the Strait of Georgia and West Coast of Vancouver Island stocks based on independent estimates from a summer trawl survey (Tanasichuk, 2000, 2002). Forecasts of age-3 recruits for the two minor herring stocks (Area 2W and Area 27) are determined by assuming "average" recruitment. Forecasts of age-3 recruits for the other three major areas are determined using recruitment forecast rules, which were developed in 2004 (DFO. 2004).

Table 3 provides forecasts of pre-fishery mature stock biomass for each major and minor area. When recruitment forecasting rules are applied, 2012 recruitment is estimated as "poor" for Haida Gwaii, Central Coast, and West Coast of Vancouver Island stocks, "average" for the Prince Rupert District and the two minor stock areas (Area 2W, Area 27), and "good" for the Strait of Georgia.

Table 3. Forecasts of pre-fishery mature stock biomass for BC herring stocks for 2012. Underlined values indicate recruitment forecasts assumed for 2012.

Stock Assessment Areas	**Recruitment Option**		
	Poor	**Average**	**Good**
Haida Gwaii Area 2E	**9,618**	12,892	21,478
Prince Rupert District	24,150	**27,492**	37,286
Central Coast	**11,357**	14,709	22,883
Strait of Georgia	94,703	112,856	**138,448**
West Coast Vancouver Island	**15,321**	20,906	31,130
Area 2W	5,294	**5,398**	6,141
Area 27	909	**1,124**	1,736

Table 4. Summary of stock assessment advice and maximum available yield for 2012. Forecast is presented as median (and 95% confidence interval).

Assessment Area	Forecast of Recruitment	Forecast of Mature Stock Biomass (tonnes)	$0.25B_0$ (tonnes)	Potential[1] Commercial Harvest (tonnes)
Haida Gwaii (Area 2E)	Poor	9,61 (1,912 – 19,470)	10,436	0
Prince Rupert District	Average	27,492 (11,149-48,923)	19,641	5,498
Central Coast	Poor	11,357 (2,866-17,511)	15,600	0
Strait of Georgia	Good	138,448 (60,379-203,017)	35,013	27,690
West Coast Vancouver Island	Poor	15,321 (2,870-19,001)	14,894	427
Area 2W	Average	5,398 (1,278-14,431)	NA	540
Area 27	Average	1,124 (341-2,364)	NA	112

[1]*Potential commercial harvest is based on previously approved harvest control rules that apply a stock-specific commercial fishery cutoff and a harvest rate of 20% for major stock assessment areas and 10% harvest rate for minor stock assessment areas. In cases where the forecast is greater than the cutoff but a 20% harvest rate would reduce the spawning biomass to below the cutoff, the maximum harvest yield is equal to the difference between the forested and cutoff amounts.*

Sources of Uncertainty

Recruitment is considered to be the most important process determining the productivity of British Columbia herring populations. Various studies have suggested that herring recruitment is determined by variations in the size of the parent stock, and environmental conditions during the first year of life. Long-term research has shown that both recruitment and adult survival tend to be below average in warm years, particularly when migratory herring-predators (like Pacific hake and mackerel) are abundant off the west coast of Vancouver Island (Ware 1991). The West Coast of Vancouver Island herring stock shows an inverse relationship between sea-surface temperature (SST) and herring production. Research is on-going and includes: monitoring of juvenile herring stocks in the SOG and CC areas and monitoring of zooplankton abundance for the WCVI.

Uncertainties in the modeling of key parameters (such as gear selectivity, the conversion factor between spawn index and spawner biomass "*q*", and the estimation of natural and fishing mortality) have a significant influence on model reconstructions of abundance which are used to make management decisions. Interactions amongst key parameters within the new model structure were thoroughly investigated, however further work is needed to understand the policy implications of the structural changes to the model and any impacts on the performance of the existing harvest control rule.

To assist managers in evaluating risk, this year's assessment includes estimates of the probabilities of not achieving established management objectives. These estimates are provided in the form of decision tables for three specific risk metrics, as follows:

1. the risk that a harvest option will result in a harvest rate that exceeds 20%;
2. the risk that a harvest option will induce a stock to fall below 0.25 B_0; and
3. the risk that the spawning biomass of a stock will decline in a subsequent year.

For areas where spawn-on-kelp fisheries occur, considerable uncertainty exists around the true levels of herring mortality and their impact on the results of the herring stock assessment models.

The retrospective analysis of stock abundance indicates that biomass has typically been over-forecast in recent years for the Prince Rupert District stock.

CONCLUSIONS AND ADVICE

A new integrated statistical catch age model (ISCAM) was used to assess the 2011 herring spawning stock biomass and forecast the 2012 pre-fishery mature stock biomass. Time series trends between the new herring ISCAM and the previous herring catch age model (HCAM) are comparable but key changes to the assessment methods this year changed the scaling of biomass estimates over the time series resulting in biomass estimates that are larger than those from the HCAM approach used in recent assessments. Scaling of the spawn abundance index during the dive era ($q<1$), parameterization of fishing gear selectivity, and the likelihood assumption for the age composition data are the main changes to the model that have affected estimates of stock levels.

The spawning stock biomass estimates for 2011 are provided in Table 2 and biomass forecasts for 2012 are provided in Table 3. Table 4 presents expected recruitment forecast categories and their respective biomass forecasts along with revised estimates of $0.25B_0$ (value of fishery cutoffs under current harvest control rules) and corresponding harvest control rule yield options.

Given that a number of alternative assumptions were implemented in developing the new ISCAM model and insufficient evaluation of the effects of these changes on the Fishery Management Framework occurred, it is recommended that a more comprehensive evaluation of the ISCAM model, and its impact on the decision rules for the herring assessment, be conducted.

Fishery managers are advised to consider risks of not achieving established management objectives. Estimated probabilities of these risks are provided in the form of decisions tables. It was recommended that additional consideration and planning occur between Science and Management to further develop applicable risk metrics for future stock assessments and approaches for application.

Haida Gwaii, Central Coast and West Coast of Vancouver Island stocks all remain at relatively low stock abundance levels. There has been little evidence of stock recovery in these areas despite the absence of commercial fishing in recent years. The causes of the recent trends in low productivity in these areas are unknown, and more work is required to address this uncertainty. Therefore, an evaluation of appropriate rebuilding and harvest strategies is recommended prior to reopening fisheries in this area

Under the assumption of "Poor" age-3 recruitment for the Haida Gwaii and Central Coast stocks, the forecast of the 2012 mature stock biomass for each of these areas is below the respective estimate of $0.25\ B_0$,.

Under the assumption of "Poor" age-3 recruitment for the West Coast of Vancouver Island, the 2012 forecast of the mature stock biomass for the West Coast of Vancouver Island is only 427 tonnes over the respective estimate of $0.25\ B_0$

Under the assumption of "Average" recruitment for the Prince Rupert District, the forecast of the 2012 mature stock biomass is 27,492 tonnes, which is greater than the estimate of $0.25B_0$ (14,894 tonnes). Due to the relatively high level of uncertainty evident in the retrospective analysis for recent biomass estimates for the Prince Rupert District, caution is advised in planning fisheries in this area. If fishing were to occur at the maximum commercial harvest option, there is about a 15% probability of exceeding the harvest rate of 20%.

The Strait of Georgia stock spawning biomass has increased since the recent relative low in 2009, due to strong 2006 and 2008 year-classes. Under the assumption of "Good" age-3 recruitment for the Strait of Georgia, the forecast of the 2012 mature biomass is 138,448 tonnes, which is greater than the estimate of $0.25B_0$ (35,013 tonnes).

Assessment of the Area 2W stock indicates that abundance has been relatively similar in the last five years, with a 2011 spawning biomass estimate of 5,448 metric tons. Under the assumption of "Average" age-3 recruitment for the Area 2W stock, the forecast of the 2012 mature stock biomass is 5,398 tonnes.

Assessment of the Area 27 stock indicates that abundance has shown some gradual declines in the past five years, with a 2011 spawning biomass estimate of 1,077 tonnes. Under the assumption of "Average" age-3 recruitment for the Area 27 stock, the forecast of the 2012 mature stock biomass is 1,124 tonnes.

SOURCES OF INFORMATION

This Science Advisory Report has resulted from the Fisheries and Oceans Canada, Canadian Science Advisory Secretariat Pacific Regional Advisory Meeting of September 7-9, 2011 on *Pacific Herring Stock Assessment.* Additional publications from this process will be posted as they become available on the DFO Science Advisory Schedule at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

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ISSN 1919-5079 (Print)
ISSN 1919-5087 (Online)

La version française est disponible à l'adresse ci-dessus.

CORRECT CITATION FOR THIS PUBLICATION

DFO. 2011. Stock Assessment Report on Pacific Herring in British Columbia in 2011. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/061.